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WORKING GROUP WRITTEN PRESENTATION

ATOMIC OXYGEN

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Earlier Shuttle flight experiments have shown NASA and SDIO spacecraft designed for operation in low-Earth orbit (LEO) must take into consideration the highly oxidative characteristics of the ambient flight environment. Although the number densities of atomic oxygen (AO) at altitudes where spacecraft typically operate (300-600 km) are quite low (10^9-10^7 atoms/cm^3), the high orbital speed of the spacecraft can result in incident fluxes (10^{14}-10^{15} atoms/S cm^2), and collisional energies (translational energies equivalent to ~60,000 °K) large enough to interact with and degrade many different kinds of material surfaces.

Materials most adversely affected by atomic oxygen interactions include organic films, advanced (carbon-based) composites, thermal control coatings, organic-based paints, optical coatings, and thermal control blankets commonly used in spacecraft applications. In addition to causing changes in the mechanical, electrical, and optical properties of these materials, atomic oxygen can also interact with spacecraft surfaces to produce chemiluminescence, or "glow" within the ultraviolet (1400-4000 A), visible (4000-8000 A), and infrared (1.2-5.5 μm) wavelength ranges. These emissions can, in turn, interfere with or obscure low-light level observations made aboard Space Station Freedom and obtained from SDI target acquisition satellites. To obtain a more basic understanding of these and other environmental interaction effects, NASA has scheduled retrieval of the LDEF (Long Duration Exposure Facility) when the Shuttle flights resume, and now has under development the EOIM-3 (Evaluation of Oxygen Interactions with Materials, third series) flight experiment to obtain accurate reaction rate measurements for a large number of materials used in spacecraft applications, and an OAST spacecraft glow experiment to quantify glow brightness as functions of orbital altitude and surface temperature and study the interaction mechanisms responsible for the glow emissions.

Earlier results of NASA flight experiments have shown prolonged exposure of sensitive spacecraft materials to the LEO environment will result in degraded systems performance or, more importantly, lead to requirements for excessive on-orbit maintenance, with both conditions contributing significantly to increased mission costs and reduced mission objectives. These problems are especially important for SDI space-based platforms launched by expendable vehicles and delivered to orbits not easily accessible for maintenance by the Space Shuttle. In addition, our laboratory and flight results represent a relatively

immature data base, and the synergistic aspects of atomic oxygen, UV radiation, ionizing radiation, and micrometeoroid/space debris impacts are not adequately understood.

Flight data obtained from previous Space Shuttle missions and results of the Solar Max recovery mission are limited in terms of atomic oxygen exposure and accuracy of fluence estimates. The results of laboratory studies to investigate the long-term (15-30 yrs.) effects of AO exposure on spacecraft surfaces are only recently available, and qualitative correlations of laboratory results with flight results have been obtained for only a limited number of materials. To resolve these limitations to our data base, the Atomic Oxygen Working Group has recommended flight experiments be developed jointly by NASA and SDIO to improve the accuracy of the data base, provide an enhanced understanding of the interaction mechanisms and establish increased confidences in system designs. These flight experiments, in order of priority, are identified as follows:

- LDEF retrieval
- EOIM-3 Atomic Oxygen Effects experiment
- Delta Star materials studies
- Small, recoverable (mini-LDEF) satellites
- LDEF re-flight
- Retrieval of operational satellites
- OAST spacecraft glow experiment

The working group has also recommended the most promising ground-based laboratories now under development be made operational as soon as possible to study the full-life (15-30 yrs.) effects of atomic oxygen exposure on spacecraft systems. These laboratories should have adequate diagnostics to fully characterize the oxygen beam, and must produce atomic oxygen fluxes sufficiently high to accomplish full-life exposure studies within reasonable periods of time. The fidelity and accuracy of these exposures would later be determined by comparing their measurement results to results obtained from the EOIM-3 and Delta Star flight experiments.